Historical Background
Togai InfraLogic, Inc.

"Togai InfraLogic, Inc., the first U.S. company dedicated to fuzzy logic, is moving rapidly to become the first world-wide full-spectrum vendor of fuzzy engineering services, software, and hardware."

- R. Colin Johnson
15 July 1991
Electronic Engineering Times

September 1991

I. Introduction

History: Togai InfraLogic, Inc. (TIL) is an Irvine, California-based corporation that has become a world leader in fuzzy logic technology in the four short years since its formation in 1987 by Dr. Masaki Togai.

As the premiere U.S. manufacturer of hardware and software products incorporating fuzzy logic, TIL has developed a vertical integration strategy of commercial and OEM products ranging from software development tools to the world's first Digital Fuzzy Processor (DFP™) chip, the FC110. The chip was awarded the Product of the Year Award in 1989 by the prestigious Electronic Products journal. TIL believes that its Digital Fuzzy Processor will set the standard for a new type of information processing, more amenable to real-world applications, where solutions to problems can be determined from vague and imprecise input data.

OEM products based on the company's technology are as diverse as factory controllers and sales prediction systems. TIL has achieved many fuzzy logic design wins, several of which are now in volume production. These include, among many products yet to be announced, a residential fuzzy air conditioner for Mitsubishi Heavy Industries, and a fuzzy autofocus 8mm video camcorder for Canon, Inc.

Togai InfraLogic, Inc. has achieved international recognition as the world leader of fuzzy logic solutions. Working as both provider and educator of fuzzy logic, Togai InfraLogic has been a major catalyst in the acceptance of this technology in the U.S. business place. Working closely with leading academic institutions such as the University of California (Irvine) and the University of Tennessee, new and improved methods of working with fuzzy logic are rapidly developing.

A recent addition to the global strength of Togai InfraLogic is the Technology Systems Division (TSD) which will focus on the integrated engineering of advanced automation technologies and the applications of fuzzy logic and neural networks.

For a listing of the company's achievements to date please see section IV, "Notable Highlights."

Objectives: TIL's objective is to be the world leader in the application of fuzzy logic technology, and to play a major role in the development of fuzzy logic based products through OEM activities and end-products based on fuzzy logic. With its VLSI based Digital Fuzzy Processor, the FC110, TIL intends to capture a major share of the upcoming market for embedded fuzzy logic applications such as machine control, real-time sensory fusion, and robotics.

Strategy: To meet its objectives the company has developed a three phase vertical strategy to maintain a competitive edge. This strategy is based on an evolutionary process of developing design tools, then fuzzy hardware, and finally specific fuzzy logic based "turn key" products.

Phase I - Design tool development. TIL has completed this phase of its strategy by shipping its fuzzy logic expert tools.

Phase II - Fuzzy hardware. The release of the proprietary VLSI Digital Fuzzy Processor has already been completed. The development of many commercial OEM applications is well under way.

Phase III - Turn key products. This phase began in December 1989 and is ongoing. It currently includes projects for applications such as motor control which involve subsystems and components incorporating fuzzy logic.

The following graphic depicts the simplicity of how TIL products work to enhance the user's capabilities on existing products and applications.

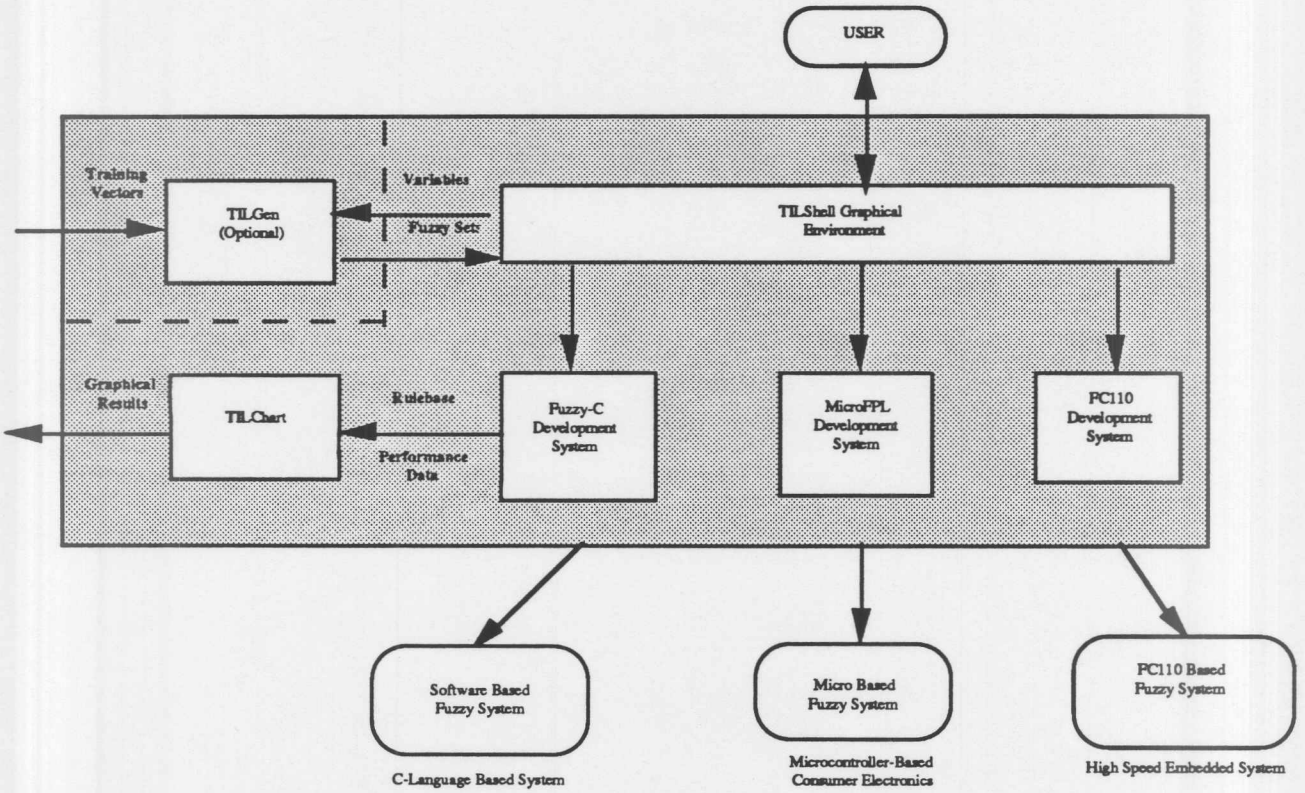

Figure 1- Togai InfraLogic, Inc. Product Family

With distributors throughout the world, TIL has clearly positioned itself as a leading edge thinker and motivator in this most exciting and dynamic of technology arenas.

Location: Togai InfraLogic, Inc. is headquartered in Irvine, California, with branch offices in Houston, Japan and Munich.

Headquarters:
Togai InfraLogic, Inc.
5 Vanderbilt
Irvine, CA 92718
(714) 975-8522
FAX (714) 975-8524

Munich:
Togai InfraLogic GmbH
Rosenstraße 7
8000 Munchen 2
Germany
(011) 49 89 2311 3867
FAX (011) 49 89 2311 3811

Houston:
17000 El Camino Real
Suite 300S
Houston, TX 77058
(713) 480 8906
FAX (713) 480 8904

Japan:
Nihon InfraLogic Ltd.
Arrow Building 5F
3-12-11 Higashi-Nihonbashi
Chuo-ku, Tokyo
103 Japan
011-81-3-3668-5466
FAX: 011-81-3-3668-5788

II. Fuzzy Logic and its Applications

Fuzzy logic is a form of multi-valued logic which makes it possible for computer controlled products to make "shades of gray" decisions the way humans do, as opposed to the limited "yes or no" approach dictated by conventional computer logic.

Fuzzy logic was first proposed by professor Lotfi Zadeh, Ph.D. of the University of California at Berkeley in 1965. Some have suggested that its acceptance in the U.S. has been delayed due to the unorthodox implications of the name.

> "I was looking for a respectable name, but settled on fuzzy logic. It was better to have a term that was accurate and self-explanatory - even though it was bound to cause some problems because of its informality and pejorative connotations."
>
> - Professor Lotfi Zadeh, 1965.

Fuzzy logic is well suited to controlling non-linear, ill-defined, and time-varying systems, and for uncertain information processing areas. Decision support systems in the financial arena is one of the markets where fuzzy logic could be quite amenable.

While fuzzy logic as a term has only been in the spotlight for the past several years, the applications of this technology have been in use since the early 1980s.

The first commercial application of fuzzy control was a cement kiln developed by F. L. Smidth & Co. of Copenhagen in 1980. In this application fuzzy logic was used to replace the aging operators who had developed their skills for controlling the kiln over several decades of experience. Since this milestone, over 100 commercial applications have become available - ranging from consumer oriented items such as cameras and washing machines to control processors, optical sensors and financial investment systems.

In the U.S. marketplace, fuzzy logic has been implemented in several medical evaluation systems as well as in defrosting units of refrigerators. Not confined to the commercial segment, government has been studying the benefits of fuzzy logic for several years, and Togai InfraLogic has provided both product and consultation to several government agencies including NASA who is presently evaluating fuzzy logic for application in shuttle orbiter positioning, whereby the skills of the best pilots can be stored in the flight control computers in the form of heuristic fuzzy logic rules.

Automobile manufacturers in Japan are implementing fuzzy logic in areas including engine control, automatic braking systems, and automatic transmission shifting. For example, Nissan has a version of the Maxima, called the Bluebird, which is currently available in Japan with a fuzzy transmission.

Europe too, has taken a strong interest in the applications of fuzzy logic and active developments are taking place in the white goods and other manufacturing industries. SGS Thomson Microelectronics, has recently launched a five-year $30 million research program to develop fuzzy logic-based hardware. Additionally, conglomerates such as Siemens have also put a heavy hand into the development of fuzzy-logic and its application to many of the company's product lines.

III. Standard Products

TIL's fuzzy logic products run from software to silicon. The illustration below outlines the company's product evolution strategy. The inner circle represents TIL's development system products which convert fuzzy expert systems to portable C source code, assembly code for specific microprocessors, or machine code for TIL's proprietary FC110 Digital Fuzzy Processor. The middle ring in the software development plan is the TILShell, a graphical object-oriented CASE tool which greatly simplifies fuzzy expert system development and provides system/project design features. Hardware products include AT and VME accelerator boards, the Single Board Fuzzy Controller, and several customer specific fuzzy processor boards. All of these board products are based on the company's proprietary Digital Fuzzy Processor, the FC110 DFP™. The outer ring continues to be developed. TILChart, a recent addition, provides graphical analysis capabilities during simulations. A key part of the outer ring is provided by TILGen, the company's development product that automatically generates fuzzy rule bases.

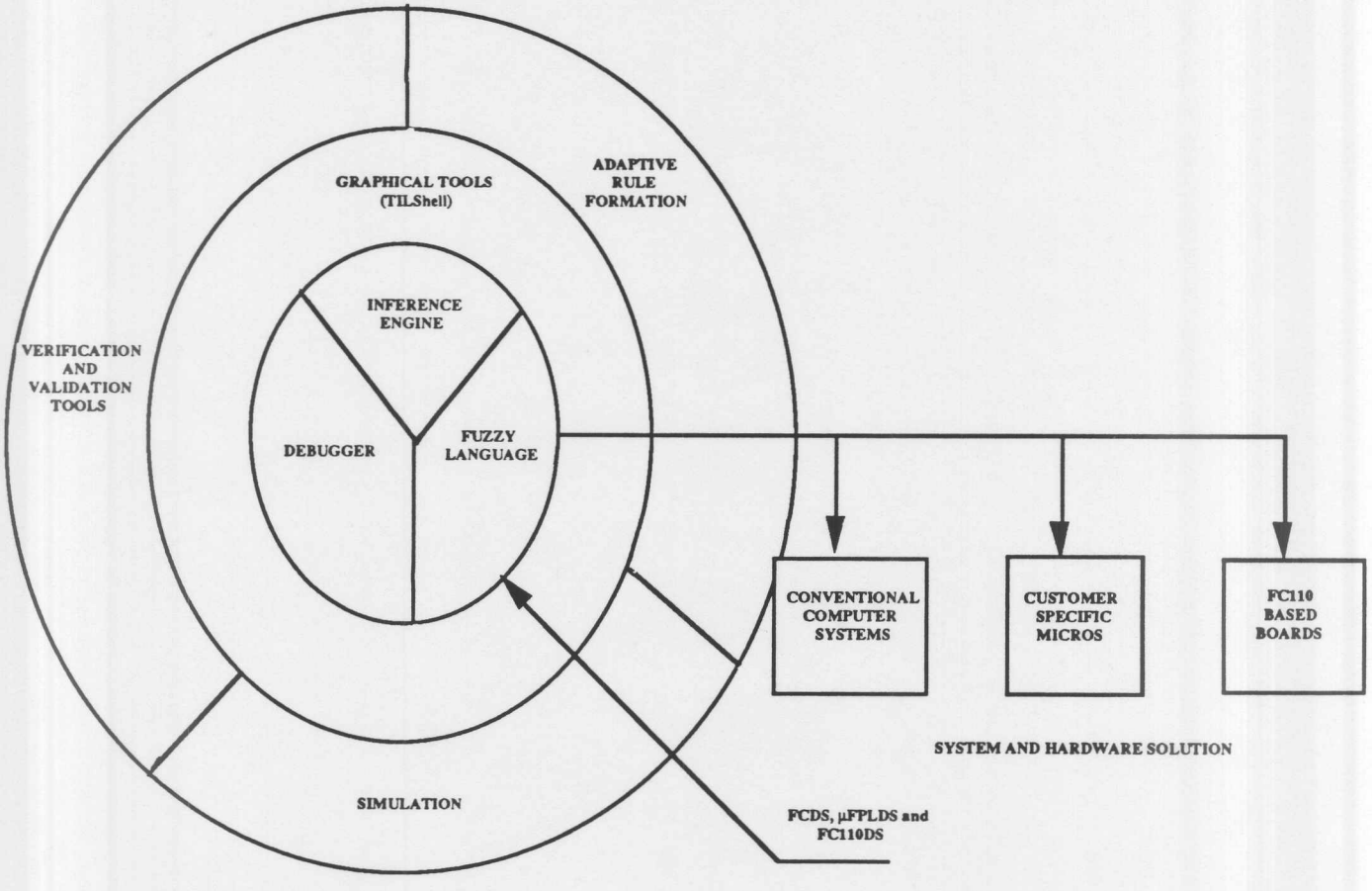

Figure 2- Togai InfraLogic Product Evolution Plan

IV. Notable Highlights

August 1987

Togai InfraLogic receives seed funding to begin operations and becomes incorporated.

October 1988

Togai InfraLogic begins full-scale operation.

December 1988

The first fuzzy logic development tool is introduced - the Fuzzy-C Compiler, a textual tool for developing fuzzy logic expert systems in portable C source code.

March 1989

The FC110 Digital Fuzzy Processor (DFP), a full custom VLSI chip designed for real-time fuzzy applications is released.

April 1989

In conjunction with ~~Sony~~ Canon, TIL develops an optical character recognition chip.

October 1989

The AT Accelerator board based on TIL's high performance VLSI fuzzy logic processor chip is introduced. The AT board is capable of executing 370,000 two premise fuzzy production rules per second and over 1 million conventional Boolean production rules per second.

October 1989

More commonly referred to as the FC110 Development module, the single board platform for developing FC110-based embedded expert systems is released.

December 1989

TIL is honored with Product of the Year for the FC110.

January 1990

The MicroFPL Development System is introduced.

March 1990

Introduction of the TILShell with graphical fuzzy editor. The TILShell is a computer aided software engineering (CASE) tool for building fuzzy expert systems.

June 1990

TIL announces the Single Board Fuzzy Controller (SBFC), designed for fuzzy logic control applications. The SBFC's multiplexed bus architecture allows the user to explore the full spectrum of possible system architectures.

July 1990

The Fuzzy VME Accelerator board using four of TIL's FC110 digital fuzzy processors is announced.

September 1990

TIL announces agreement with Hitachi to develop a chip utilizing MicroFPL.

December 1990

Based on fuzzy logic control technology developed jointly with Togai InfraLogic, the air conditioner from Mitsubishi Heavy Industries offering dramatic performance improvements over conventional systems is made available in Japan.

June 1991

Classifier/Sorter (C/S) device is announced for commercial sale. The C/S product is designed primarily to accelerate the tasks required for high speed pattern recognition systems and other classification operations.

June 1991

TILGen, an automated rulebase generation tool is announced. TILGen allows the user to automatically generate fuzzy rulebases.

June 1991

Fuzzy-C Development System 2.3 is released.

July 1991

TIL GmbH begins operation in Munich, Germany.

September 1991

TIL Technology Systems Division goes into operation.

V. Personnel Overview

Masaki Togai, Ph.D. is Chief Executive Officer and founder of Togai InfraLogic, Inc. Dr. Togai has spent the last ten years leading fuzzy logic development groups at Duke University, AT&T Bell Laboratories, and Rockwell International. He is best known in the industry for developing the world's first fuzzy microchip for real-time approximate reasoning while at AT&T Bell Laboratories.

Dr. Togai is a member of the research steering committee on the MITI LIFE project, a member of the Board of Directors of the North American Fuzzy Information Processing Society (NAFIPS), and a member of the American Association of Artificial Intelligence, IEEE, the International Fuzzy Systems Association (IFSA) and Sigma Xi. He is presently serving as the editor-in-chief of the *Japan Artificial Intelligence Newsletter*, and the *Journal of Approximate Reasoning*. He is the author of two books: *Intelligent Robotic Systems* and *Approximate Reasoning in Expert Systems*. He received his M. S. and Ph.D. degrees in Electrical Engineering in 1977 and 1982, respectively, from Duke University.

Robert H. Brown is President of the Technology Systems Division. Mr. Brown previously organized and managed the first AI efforts to come out of the Johnson Space Center which grew to a staff of over 100 with revenue of $18M. Mr. Brown brings to TIL his expertise in managing advanced automation technology with a keen insight into the international scenario of fuzzy logic and robotics.

Jack Aldridge, Ph.D., is a vice-president of the Technology Systems Division. Dr. Aldridge is a recognized leader in the field of AI. He is a key member of the corporate Automation and Robotics planning activities. Dr. Aldridge brings to Togai strong capabilities in the academic and seminar arenas. As a former chief scientist at McDonnell Douglas, Dr. Aldridge encompasses a wide array of artificial intelligence arenas with keen understanding of the applications of fuzzy logic to the general market.

Yashvant Jani, Ph.D, is a vice-president of the Technology Systems Division and has spent many years developing fuzzy logic for space operations. Dr. Jani provides a network of national and international resources in the fields of fuzzy logic, neural networks and expert systems. Dr. Jani is a recognized expert on fuzzy logic applications to control processing.

In addition to the above, TIL retains the skills of a highly qualified team of software and hardware engineers whose talents cover a large spectrum of industries. Internal expertise with major automotive manufacturers, semiconductor and aerospace firms are just a few of the areas where corporations have turned to TIL staff for consultant and custom-designs for fuzzy-logic based products.

The attached appendix provides possibilities for ways in which users can begin incorporating fuzzy logic into their processes today.

Togai InfraLogic, Inc. Product Package Recommendations

If one is just curious about fuzzy logic...

If one plans on developing a simple fuzzy logic prototype system or would simply like to experiment with fuzzy logic, the Personal Fuzzy-C Development System is recommended. It is an inexpensive and cost-effective way to allow for a good training session on what a fuzzy system can do.

RECOMMENDATION: Personal FCDS.

If one is planning serious fuzzy logic development in C Language...

The TILShell/FCDS combination will give the user the ability to develop sophisticated fuzzy logic systems for any target processor with a C compiler. This package also includes the TILChart.

RECOMMENDATION: TILShell/FCDS Package.

If one is planning fuzzy logic development for an 8-bit microprocessor...

The TILShell/FCDS System can be used to prototype and debug a system in a high level language. The MicroFPL Development System is then used to generate assembly code for final system integration and ROM or EPROM programming.

RECOMMENDATION: TILShell/FCDS package and MicroFPL Development System.

If one is planning fuzzy logic development and will need very high performance...

If one is looking to develop a system on the IBM-PC, the AT Development Package is recommended. This kit includes the TILShell, the FC110 Development System, and an FC110-based IBM-PC accelerator card. Otherwise, for bread-boarding a custom system using the FC110, the SA Evaluation Kit is recommended. This kit includes the FC110 Development System and a small form-factor FC110-based board suitable for low cost embedded applications.

RECOMMENDATION: AT Development Package or SA Evaluation Kit.

If one needs automatic fuzzy rulebase generation...

In the case of extremely complex or human controlled systems, fuzzy logic control rules are often difficult to obtain. TILGen is a neural network-based tool that can automatically generate these rules by monitoring the user's system (in the form of training vectors) and then by training on this data generate the fuzzy logic control rules that duplicate the performance of the system.

RECOMMENDATION: TILShell/FCDS/TILGen Package.

NEWS

Togai InfraLogic, Inc.
5 Vanderbilt
Irvine, California 92718

For further information contact:
Camerone Welch
Phone (714) 975-8522
FAX (714) 975-8524

TOGAI INFRALOGIC, INC. ANNOUNCES DUAL PROCESSOR SBUS ACCELERATOR BOARD FOR FUZZY LOGIC

IRVINE, Calif., October 31, 1991 -- Togai InfraLogic, Inc. (TIL) today announced the latest addition to its hardware product line: a dual-processor SBus accelerator board for workstation and industry control applications of fuzzy logic.

The Togai InfraLogic SBus board is a high performance single board fuzzy logic accelerator designed for complex real-time fuzzy logic applications on SBus based machines. Based on Togai InfraLogic's custom VLSI processor, the FC110 DFP™ (Digital Fuzzy Processor), this board brings a full range of fuzzy control system capability to SBus-based equipment- up to 440,000 fuzzy rule evaluations per second (including defuzzification).

The SBus accelerator board is designed around two fully supported FC110 Digital Fuzzy Processors. The FC110 is a RISC processor that contains a specialized fuzzy instruction set, allowing it to evaluate complex fuzzy problems more quickly than conventional processors.

The Togai InfraLogic SBus accelerator board uses the latest in SMT and programmable array logic technology. The six-layer double-sided board is manufactured using a dry etch process. All bus driver interface logic uses series output resistors to reduce overall system noise and suppress ground bounce effects.

- more-

Among the applications for which the SBus is well suited are:

- Factory Automation
- Motor Control
- Robot Arm Control
- Pattern Recognition and Classification
- Real-Time Process Control
- Sensor Fusion
- High Level Task Scheduling

Additionally, the on-board multi-processor capability can be applied to complex systems requiring simultaneous processing of multiple independent knowledge bases or for processing a single knowledge base in parallel. Parallel processing is available on-board via two FC110 processors. Parallel processing gives control system designers flexibility to provide speed and performance for multiple, integrated control problems.

Fuzzy logic knowledge bases are compiled using the FC110 Compiler which accepts a subset of FPL, Togai InfraLogic's Fuzzy Programming Language. Fuzzy logic production rules and membership functions are compiled directly into FC110 machine language. The use of a uniform development language allows knowledge bases to be written once and compiled to various target implementations from workstations to PCs, to microcontrollers and to embedded FC110 systems without additional development.

In addition, Togai InfraLogic's TILShell™ window based software development environment interfaces directly with the FC110 Compiler. Combining the SBus Accelerator Board, the FC110 Compiler and the TILShell interface, provides the user with the ability to turn an SBus, Unix-based computing platform into a fuzzy control system engineering workstation.

According to Daniel Bochsler, Vice President, Operations and Marketing, the development of the SBus Accelerator Board "represents Togai InfraLogic's initial step in meeting the market needs brought on by the convergence of computers and controllers in the controls market today."

Pricing for the SBus board and development packages will be announced shortly, with availability of the products in early first quarter 1992.

Togai InfraLogic, Inc. (TIL), a privately held firm based in Irvine, California, is a leading worldwide provider of hardware and software products incorporating fuzzy logic technology.

Founded in 1987, with branch offices in Houston, Japan and Munich, TIL products and design expertise have been put to work in a host of high volume commercial applications. Examples include residential air conditioner control, VCR commercial focusing and steel mill pressing units.

###

Attention Editors: Photographs of The SBus Accelerator Board are available upon request.